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(54) **Surface blasting system**

Bodenflächesprengsystem

Système de sautage de surface de sol

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Description

BACKGROUND OF THE INVENTION

THIS invention relates to a method of and an apparatus for activating a plurality of groups of electrical loads such as electrically activated detonators. The invention has particular application in surface blasting techniques.

When carrying out a blasting operation on the surface of, for example, a quarry, the area of the blast may be very large. For example, an area of 500 m by 60 m (30 000m^2) may be covered. This area may have, say, 300 holes, with multiple detonators per hole if the decking principle is used.

If electronically controlled detonators are used, the total length of the harness wires required to control the blast may be several kilometres. This can cause problems in powering and synchronizing all of the delay devices. Given the fact that the value of the explosive used in such a large blast may be of the order of several hundred thousand rand, it is very important to maintain timing accuracy when carrying out such blasts. It is also important to maintain safety standards in such blasts.

In the prior art, it is known to provide control arrangements with a single, central control unit to control a plurality of detonator circuits. Individual detonator circuits include command decoders to decode commands received from the central control unit.

SUMMARY OF THE INVENTION

According to the invention there is provided a blasting control apparatus for activating a plurality of groups of electrically activated detonators after respective predetermined time delays comprising a master control unit, and a plurality of auxiliary control units each adapted to control a respective group of remote electrical delay devices which are associated with corresponding electrically activated detonators, characterised in that the master control unit comprises:

master processor means adapted to generate master programming signals corresponding to an activation sequence for the detonators of each group of electrically activated detonators, a plurality of communications interfaces for transmitting the master programming signals to respective auxiliary control units, reference timing means for generating a master timing signal for transmission to each auxiliary control unit, and control means for generating master control signals corresponding to an initiation instruction for the electrical delay devices; and further characterised in that each auxiliary control unit is connectable to the master control unit and comprises:

local processor means responsive to the master programming signals to generate local programming signals to program the operation of the respective group of remote electrical delay devices in accordance with the activation sequence, synchronisation means for generating local timing signals in synchronisation with the master timing signal, energisation means adapted to supply electrical power to the electrical delay devices and corresponding electrically activated detonators, and local control means for generating local control signals from the master control signals which are synchronised with local control signals of other auxiliary control units, when the apparatus is in use, for initiating operation of the electrical delay devices of the respective group of electrically activated detonators, so that the activation sequences of the electrically activated detonators of each group of electrically activated detonators are synchronised.

The electrically activated detonators each have an associated electrical delay device.

The master control unit may comprise master processor means for generating a blast pattern including activation sequences for the detonators of each group of detonators.

Each auxiliary control unit may include an auxiliary communication interface for receiving the master control signals from the central control unit and for transmitting data representative of the operational state of the auxiliary control unit to the master control unit.

In a preferred embodiment of the invention, the synchronisation means of each auxiliary control unit comprises a local oscillator for generating a primary local clock signal at a frequency higher than that of the master timing signal, frequency adjustment means for incrementally increasing or decreasing the frequency of the primary local clock signal in response to correction signals, frequency divider means for reducing the frequency of the primary local clock signal to a frequency dose to that of the master timing signal, and comparator means for comparing the output of the frequency divider with the master timing signal and for generating correction signals which are applied to the frequency adjustment means so that the output frequency of the frequency divider means approaches that of the master timing signal.

Preferably, the frequency adjustment means comprises a multiplexer, a pulse adder circuit connected between the local oscillator and a first input connected between the local oscillator and a first input of the multiplexer, and a pulse subtracter circuit connected between the local oscillator and a second input of the multiplexer, with the output of the local oscillator being connected directly to a third output of the multiplexer, one of the first, second and third inputs of the multiplexer being selected in response to the correction signals to adjust the frequency of the primary local clock signal at an output of the multiplexer incrementally.

The synchronisation means of each auxiliary control unit may be arranged to generate the local timing signals, which have been synchronised with the master timing signal, independently of the master timing signal for a predetermined period prior to activation of the re-

spective electrical detonators.

Preferably, the master control unit is adapted to receive data corresponding to the activation sequence for the detonators of all of the groups of electrical detonators from an auxiliary computer, and to transfer data corresponding to the activation sequence for the detonators of each group of electrical detonators to the respective auxiliary control unit.

The master control unit may be adapted to receive data from each auxiliary control unit corresponding to the operational status thereof, and to transfer the received data to the auxiliary computer so that the status of each auxiliary control unit can be monitored centrally.

Further according to the invention there is provided a method of activating a plurality of groups of electrical detonators, each having an associated electrical delay device, after respective predetermined time delays, characterised in that the method comprises:

transmitting master programming signals corresponding to an activation sequence for the electrical detonators of each group of electrical detonators from a master control unit to each of a plurality of auxiliary control units;

generating local programming signals at each auxiliary control unit from the master programming signals and transmitting the local programming signals to the electrical delay devices of the respective groups of electrical detonators, thereby to program the operation of each electrical delay device and its associated detonator;

generating master control signals at the master control unit corresponding to an initiation instruction for the electrical delay devices associated with the respective detonators of each group of electrical detonators, and transmitting respective master control signals to each auxiliary control unit;

generating master timing signals at the master control unit and transmitting the master timing signals to each auxiliary control unit;

generating local control signals at each auxiliary control unit from the master control signals and the master timing signals, the local control signals of each auxiliary control unit being synchronised with one another, for initiating operation of the electrical delay devices of the respective group of electrical detonators; and

energising the delay devices and their associated detonators to activate the detonators, so that the activation sequences of the electrical detonators of each group of electrical detonators are synchronised.

The method may include generating local timing signals at each of the auxiliary control units which are synchronized with the local timing signals of other auxiliary control units, and generating the local control signals synchronously with the respective local timing signals.

The method may include generating the local timing signals in synchronisation with the master timing signal.

The master control signals may be generated in accordance with a blast pattern which is configured on a computer.

Probably, the method includes laying out the blast pattern graphically on a display of the computer.

The method may include programming each delay device with a respective delay time.

The delay times for respective delay devices may be programmed automatically, using a stored timing pattern.

The programmed delay times may be adjusted in accordance with a chosen blast parameter to optimise that parameter.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic diagram of a distributed blasting system according to the invention;

Figure 2a is a schematic block diagram of an auxiliary control unit according to the invention;

Figure 2b is a schematic block diagram of timing synchronisation circuitry of the auxiliary control unit;

Figure 3 is a simplified block diagram of a central control unit according to the invention;

Figure 4 is a simplified flow diagram illustrating the overall operation of the system;

Figures 5 to 9 are flow diagrams illustrating different aspects of the operation of the system in more detail; and

Figure 10 is a diagrammatic illustration of a typical multizone blasting pattern.

DESCRIPTION OF EMBODIMENTS

The schematic diagram of Figure 1 illustrates a distributed blasting system in which a master control unit (or blast controller) 10 controls five separate auxiliary control units 12 (referred to as "zone amplifiers" in Figure 1) via communication/timing cables 14. Each auxil-

iary control unit 12 controls a number of electronic delay detonators (EDD's) 16 in respective boreholes, via a bi-directional harness 18. The detonators are programmed via the harness using the techniques described in South African patent application number 90/7794, the contents of which are incorporated herein by reference.

In the illustrated example, the entire blasting area is a rectangle approximately 500m by 60m, with each blasting zone being approximately 100m by 60m in size.

Figure 2a is a block diagram showing the basic configuration of an auxiliary control unit (or zone amplifier) 12. The auxiliary control unit is similar to the controller illustrated in Figure 2 of South African patent application no. 90/7794. The auxiliary control unit is based around a microprocessor 20, and includes a communication interface 22 and a local clock generator circuit 60 which receive control signals and master timing reference or clock signals, respectively, via a communication/timing cable 14 from the master control unit. The functioning of the auxiliary control unit is similar to that of the controller described in South African patent application no. 90/7794 (to which EP-A-0420673 is an equivalent disclosure).

However, an additional power supply test load section 38 is provided to enable the detonator power supply 50 to be fully functionally tested before use. This is very important in a distributed blasting system of the kind described, since the failure of one of the auxiliary control units would cause an overall failure of the blast. The microprocessor 20 also controls a safety motor interlock 52, which in turn controls safety switches 54. This ensures that this system is operating and that the lines to the detonators are all shorted to ground and to each other when the system is being connected up initially. The auxiliary control unit includes a detonator programming line monitor 56 and a programming pulse generator 58. These circuits, together with the safety motor interlock 52 and the safety switches 54, are described in the abovementioned patent application.

Figure 2b is a schematic block diagram of the timing synchronisation circuitry of the auxiliary control unit (or zone amplifier) 12, which comprises mainly the local clock generator circuit 60 and the microprocessor 20.

The local clock generator circuit 60 includes a line receiver 62 and a time synchronisation circuit with its own local oscillator or clock generator 24. The local oscillator 24 is a stable, crystal controlled oscillator which runs at 10kHz, and its output, which can be regarded as a "raw" or primary clock waveform, is fed to a pulse adder 26 and a pulse subtractor 28, the outputs of which are fed, together with the clock signal itself, to three inputs of a multiplexer 30. The pulse adder and subtractor add or subtract one pulse per second to the output of the clock generator 24. The output of the multiplexer is fed to a frequency divider 32, which divides the 10 kHz signal by a factor 10 000, to provide a 1 Hz (1 pulse per second) output. A logic comparator circuit 34 compares the locally generated 1 Hz signal with a 1 Hz master timing signal received from the master control unit 10 via the cable 14 and the line receiver 62, and generates correction signals which are fed to a logic circuit 36. This circuit selects one of the three multiplexer inputs, depending on whether the local clock signal is early, on time, or delayed with respect to the master clock signal. If correction is required, the frequency of the local clock signal is thus adjusted incrementally so that the output of the frequency divider 32 tends towards the master clock signal, until synchronisation is achieved.

The above described time synchronisation circuit is substantially noise immune, in that the adjustments made when synchronising the local clock square wave to the master clock square wave are done in very small steps, so that any noise spikes cannot suddenly cause the synchronisation to change. Once blasting begins, noise may be generated on the timing cables. For this reason, the synchronisation process is stopped when (or just before) blasting commences, and each auxiliary control unit runs on its own clock or timing signal, as most recently synchronised with the master timing signal from the master control unit. Since the local square wave oscillator 24 of each auxiliary control unit is crystal controlled, it maintains the necessary accuracy over the required (relatively short) period until the blast occurs.

The above described time synchronisation circuit ensures that each of the auxiliary control units synchronises its local clock signal to the master clock signal of the master control unit, by effectively adjusting the local clock signal until it matches the received master clock signal within a predetermined tolerance. However, other ways of synchronising the operation of the different auxiliary control units are possible. For example, the master control unit and the auxiliary control units can each be fitted with real time clocks. These clocks are all set to exactly the same time prior to the setting up of a blast. To carry out the blast, the auxiliary control units are instructed by the master control units to initiate their respective groups of detonators at a specific time. This system relies on the accuracy of the real time clocks, and does not require a comparison and feedback process such as that carried out by the above described time synchronisation circuity. Factors which would influence the choice of synchronisation system would include the cost of the relevant components and the degree of accuracy achievable, according to the specific application.

Another approach which can be followed to achieve synchronisation between the operation of the different auxiliary control units is to arrange for the master control unit to send respective accurately synchronised control signals to each of the auxiliary control units, and for the auxiliary control units to be designed to introduce a negligible or at least a uniform time delay in initating the operation of each respective group of electrical loads. In such an arrangement, the cables between the master control unit and each auxiliary control unit should be identical, to ensure that any delays introduced by the cables would be the same for each auxiliary control unit.

In a variation of this approach, a very high speed communication medium such as optical fibre cables or radio transmitters/receivers could be provided between the master control units and the auxiliary control units, so that timing differences due to different distances between the master control unit and various auxiliary control units would be negligible.

The above described auxiliary control unit has fewer controls compared with the original controller of the abovementioned patent application, and these comprise only a "cancel" switch and a power switch. However, all other features and functions of the original controller are attained, including its safety measures.

Figure 3 shows the general configuration of the master control unit or blast controller 10. This unit comprises a master microcomputer 40 and a reference timing unit (or master clock) 42 for generating reference or master timing signals which are transmitted to the auxiliary control units via five communication interface circuits 48, each incorporating a line driver for communicating with a respective auxiliary control unit 12. The master control unit also includes a laptop computer 44 with a display 46 for the entry of data and instructions. The computer 44 can be used by an operator to plan the blast layout, to simulate the results of the blast, to test the overall system and the electronic delay devices, and to initiate the blast.

The laptop computer communicates with the microcomputer 40 via an RS232 serial link. The microcomputer 40 in turn communicates with the auxiliary control units 12 via the respective communication interfaces 48 and the cables 14. The various blasting commands and the blasting pattern tables generated by the software in the laptop computer are transferred to the microcomputer 40, which in turn transfers the relevant commands and tables to the respective auxiliary control units (zone amplifiers) 12. The same information may be sent to each auxiliary control unit 12, or each auxiliary control unit may receive specific instructions which are unique to a particular blasting zone.

The communication interfaces of the master control unit and the respective auxiliary control units allow serial communication between the master control unit and the respective auxiliary control units over the communication timing cable 14, which may be up to 1.2 kilometres in length. Via the communication interfaces, the master control unit can instruct each auxiliary control unit to perform the various phases of the blasting procedure, that is, testing the number of detonators, programming the detonators, and initiating the detonators. The blast pattern table generated in the laptop computer 44 is transferred to each auxiliary control unit, and the status of each auxiliary control unit is monitored according to predetermined criteria. The serial number of the auxiliary control unit, which is a number in the range of 0 to 255, can be read, as can the number of detonators counted during testing of the system. Each auxiliary control unit also performs a full functional test on itself when it is powered up, by switching in dummy loads across its various output power supplies and signal lines to verify functioning.

The main or reference timing unit 42 of the master control unit generates a crystal controlled square wave of 1Hz. This square wave serves as a master timing or master clock signal which is transmitted directly via the communication/timing cables 14 to the time synchronisation circuit of each auxiliary control unit 12. As described above, the time synchronization circuit locks the local square wave clock signal to the master square wave signal from the master control unit, with an accuracy of within 0.1 ms. The microprocessor 20 in the auxiliary control unit then uses this synchronised local clock signal as a timing reference when initiating its electronic delay detonators.

The local clock signal is used to control the timing of the initiation of the detonators connected to each auxiliary control unit so that they are initiated at the correct time with respect to the detonators connected to other auxiliary control units. Thus, the local clocks or timing signals generated by the respective auxiliary control units, which are used to control the timing of the initiation of the electronic delay detonators, are synchronised to an accuracy of at least 0.1 ms across the entire blasting zone.

The flow diagram of Figure 4 illustrates the general operation of the system, while the flow diagrams of Figures 5 to 9 illustrate different aspects of the operation of the software of the system in more detail. Figure 5 is an overall operational flow diagram indicating the various operating modes of the blasting software. The diagrams of Figures 6a to 6c illustrate the blast pattern planning procedure which is carried out on the laptop computer 44 associated with the master control unit. The flow diagram of Figure 7 illustrates the set-up procedure in which the auxiliary control unit serial numbers and harness connector numbers are entered for each auxiliary control unit. Figure 8 shows the testing procedure controlled by the blasting software, and Figure 9 shows the actual blasting or detonator initiation procedure.

Referring to Figures 5 and 6a to 6c, the sequence of operation of the system begins with the operator planning the blast using the laptop computer 44. The special purpose blast planning software has a graphical CAD-like interface. This allows the operator to graphically lay out the blast using a pointing device such as a mouse or a "roller ball". The operator begins by drawing in the geometry of the rock to be blasted, including specifying the free face (if there is a free face). The blast holes are then added, with a single detonator associated with each hole. This can either be done manually by positioning each hole one at a time, or automatically from a library of previously stored patterns. To assist in placing the holes accurately, grid lines and a ruler are provided. The spacing between grid lines can be specified and a "snap to grid" feature can be used when adding holes. The ruler is used for measuring the distance between

two points on the plan. Additional information such as the hole diameter and hole depth is also associated with each hole.

Multiple detonators can be added to holes that require them. The holes are intially placed with single detonators, and additional detonators can then be added to them. Multiple detonators are used for redundancy or for decking. (Decking comprises breaking up the blast hole into vertical sections of explosives with each section being separated from the next by means of sand or air bags. Separate detonators with different delay times are placed in each section of explosives. This system might be used to blast a layer of coal out from underneath the overlying rock). The multiple detonators in a hole are indicated graphically on the blast plan.

Delay times are then added to the detonators. This can be done manually by selecting a detonator and then specifying the delay time for that detonator, or it can be done automatically from a previously stored timing pattern. Once all the times have been added the blast can be graphically simulated. This allows the operator to check that the order of initiation of the detonators and the delay timing of the detonators is acceptable. It is possible at this point to execute blast optimisation software. This software adjusts the planned delay times to give the best performance for a chosen parameter, for example, better rock fragmentation, reduced ground vibration or reduced air blast levels. The relevant criteria for each parameter are included in the software.

The above steps may have to be repeated a number of times until the operator is completely satisfied with the blast plan. Once the blast plan is complete, the software automatically places the required number of auxiliary control units on the plan, based on the predicted electrical performance of the length of cable and the number of detonators to be connected. Subpatterns with the relevant timing subpattern are generated for each auxiliary control unit used. Finally, layout instructions are generated for the blaster in charge of the blast. These can either be in the form of a tabulated set of instructions or in the form of a graphical plot of the blast layout.

From the layout instructions generated, the blaster connects up the blast. The detonators are placed in the blast holes with the bulk explosives. A harness cable is connected to each of the detonators in the zone of the relevant auxiliary control unit. The harness cable is manufactured in long rolls with a standard spacing between connectors (dependent on the mine's requirements). In use, a piece of cable is cut from the roll and used for the harness. Each of the connectors on the roll is numbered, for example, from 1 to 1000. The connector numbering allows checking that the correct number of detonators is connected to an auxiliary control unit for a specific zone and also enables the location of any faults to be indicated to the blaster.

The blaster can also plug a "bypass" into the harness connectors. A dummy plug or "bypass" bridges the signal lines of the connector that it is plugged into. A "bypass" would be used where a hole is indicated on the plan but the hole was not actually drilled, or where the cable connector spacing is not long enough to reach the next hole.

The harness is connected to the auxiliary control unit by means of two "lead ons". The "lead ons" plug into two detonator sockets on the harness cable. It is imperative that the order of connection is maintained i.e. that the start "lead on" is plugged into the start of the harness and that the end "lead on" is plugged into the end of the harness. Arrows indicating the start to end direction can be printed onto the harness connectors and onto the "lead on" connectors to aid the blaster. At the auxiliary control unit the ends of the "lead ons" can have differently shaped connectors to ensure the correct order of start and end is maintained.

The above steps are repeated for each of the auxiliary control units. The auxiliary control units are all connected to the master control unit. The master control unit can be up to 1200 meters from the auxiliary control units. Each of the auxiliary control units has a serial number, with the different auxiliary control units used in a particular blast having different serial numbers. The serial number enables the surface blasting system to check that the auxiliary control units have been connected to the main control unit in the correct order. The serial number is typically printed on the outside of the auxiliary control unit. Prior to the blaster beginning with the testing of the detonators, he must enter into the laptop computer the serial number of the auxiliary control units for each of the zones, the start and end harness connector numbers for each of the zones, and the connector numbers of any "bypasses" used (these numbers will be gathered by the blaster from inspection). The entering of this setup data is shown in Figure 7.

Once the detonators have been connected to each auxiliary control unit by means of the harness, the detonators can be tested (see Figure 8). The laptop computer 44 communicates with the auxiliary control units and checks that the serial numbers entered by the blaster are in fact correct. If not, an error is reported to the blaster. The software then operates to cause the auxiliary control units to be synchronised to a test master timing signal and instructs each auxiliary control unit to perform a functionality test on itself. This test includes testing of the signal lines and power supplies with dummy loads. Any faults are again reported to the blaster.

The software then instructs the auxiliary control units to perform a test on their respective attached detonators. Each of the auxiliary control units reports the number of detonators found and whether the attached harness is continuous from the start to end points. The software then compares the number of detonators found against the planned number of detonators, less the number of "bypasses". If these numbers do not match then a fault is indicated to the blaster. The indication of the fault can be shown graphically and can also be given

as a connecter number with the respective auxiliary control units serial number. The connector number of the faulty detonator is calculated from the start and end connector numbers typed in by the blaster. If any faults are detected then the blaster is required to fix them using the information given to him by the software. Once the fault has been corrected then the above procedure is repeated until all the faults have been corrected. The system is now ready to initiate the detonators.

Referring now to Figure 9, the software waits for the blaster to issue the instruction to blast. Once the blast instruction has been issued, then the auxiliary control units are synchronised to the master timing signals of the master control unit. The detonator delay times (or blast patterns) are transferred from the master control unit to the auxiliary control units, with each of the auxiliary control units receiving the respective delay times for its attached detonators. Each detonator attached to each auxiliary control unit is then programmed with its respective delay time and the sirens are sounded. The detonators are energised and then instructed to start their attached detonator timers using the synchronisation means. The entire system is then made safe and shut down.

A practical example of a blast pattern is shown in Figure 10, with three different blast zones controlled by respective auxiliary control units 12. Each detonator in Figure 10 is numbered and the figures in brackets indicate the delay time in milliseconds programmed into each detonator. The dotted lines indicate detonators which are timed to explode at the same time.

Claims

1. Blasting control apparatus for activating a plurality of groups of electrically activated detonators after respective predetermined time delays comprising a master control unit (10), and a plurality of auxiliary control units (12) each adapted to control a respective group of remote electrical delay devices (16) which are associated with corresponding electrically activated detonators, characterised in that the master control unit comprises:

   master processor means (40) adapted to generate master programming signals corresponding to an activation sequence for the detonators of each group of electrically activated detonators, a plurality of communications interfaces (48) for transmitting the master programming signals to respective auxiliary control units, reference timing means (42) for generating a master timing signal for transmission to each auxiliary control unit, and control means for generating master control signals corresponding to an initiation instruction for the electrical delay devices; and further characterised in that each auxiliary control unit is connectable to the master control unit and comprises:

   local processor means (20) responsive to the master programming signals to generate local programming signals to program the operation of the respective group of remote electrical delay devices in accordance with the activation sequence, synchronisation means (60) for generating local timing signals in synchronisation with the master timing signal, energisation means (50, 54) adapted to supply electrical power to the electrical delay devices and corresponding electrically activated detonators, and local control means (20) for generating local control signals from the master control signals which are synchronised with local control signals of other auxiliary control units, when the apparatus is in use, for initiating operation of the electrical delay devices of the respective group of electrically activated detonators, so that the activation sequences of the electrically activated detonators of each group of electrically activated detonators are synchronised.

2. Apparatus according to claim 1 characterised in that the electrically activated detonators each have an associated electrical delay device (16).

3. Apparatus according to claim 2 characterised in that the master control unit (10) comprises master processor means (40) for generating a blast pattern including activation sequences for the detonators of each group of detonators.

4. Apparatus according to any one of claims 1 to 3 characterised in that each auxiliary control unit (12) includes an auxiliary communication interface (22) for receiving the master control signals from the central control unit (10) and for transmitting data representative of the operational state of the auxiliary control unit to the master control unit.

5. Apparatus according to any one of claims 1 to 4 characterised in that the synchronisation means (60) of each auxiliary control unit (12) comprises a local oscillator (24) for generating a primary local clock signal at a frequency higher than that of the master timing signal, frequency adjustment means (26, 28, 30) for incrementally increasing or decreasing the frequency of the primary local clock signal in response to correction signals, frequency divider means (32) for reducing the frequency of the primary local clock signal to a frequency close to that of the master timing signal, and comparator means (34, 36) for comparing the output of the frequency divider with the master timing signal and for generating correction signals which are applied to the frequency adjustment means so that the output frequency of the frequency divider means approaches that of the master timing signal.

6. Apparatus according to claim 5 characterised in that the frequency adjustment means (26, 28, 30) comprises a multiplexer (30), a pulse adder circuit (26) connected between the local oscillator and a first input (A) of the multiplexer, and a pulse subtracter circuit (28) connected between the local oscillator and a second input (C) of the multiplexer, with the output of the local oscillator being connected directly to a third input (B) of the multiplexer, one of the first, second and third inputs of the multiplexer being selected in response to the correction signals to adjust the frequencyof the primary local clock signal at an output of the multiplexer incrementally.

7. Apparatus according to any one of claims 1 to 6 characterised in that the synchronisation means (60) of each auxiliary control unit (12) is arranged to generate the local timing signals, which have been synchronised with the master timing signal, independently of the master timing signal for a predetermined period prior to activation of the respective electrically activated detonators.

8. Appratus according to any one of claims 1 to 7 characterised in that the master control unit (10) is adapted to receive data corresponding to the activation sequence for the detonators of all of the groups of electrically activated detonators from an auxiliary computer (44), and to transfer data corresponding to the activation sequence for the detonators of each group of electrically activated detonators to the respective auxiliary control unit (12).

9. Apparatus according to claim 8 characterised in that the master control unit (10) is adapted to receive data from each auxiliary control unit (12) corresponding to the operational status thereof, and to transfer the received data to the auxiliary computer (44) so that the status of each auxiliary control unit can be monitored centrally.

10. A method of activating a plurality of groups of electrical detonators, each having an associated electrical delay device, after respective predetermined time delays, characterised in that the method comprises:

transmitting master programming signals corresponding to an activation sequence for the electrical detonators of each group of electrical detonators from a master control unit (10) to each of a plurality of auxiliary control units (12);

generating local programming signals at each auxiliary control unit (12) from the master programming signals and transmitting the local programming signals to the electrical delay devices (16) of the respective groups of electrical detonators, thereby to program the operation of each electrical delay device and its associated detonator;

generating master control signals at the master control unit (10) corresponding to an initiation instruction for the electrical delay devices (16) associated with the respective detonators of each group of electrical detonators, and transmitting respective master control signals to each auxiliary control unit (12);

generating master timing signals at the master control unit (10) and transmitting the master timing signals to each auxiliary control unit (12);

generating local control signals at each auxiliary control unit (12) from the master control signals and the master timing signals, the local control signals of each auxiliary control unit being synchronised with one another, for initiating operation of the electrical delay devices (16) of the respective group of electrical detonators; and

energising the delay devices (16) and their associated detonators to activate the detonators, so that the activation sequences of the electrical detonators of each group of electrical detonators are synchronised.

11. A method according to claim 10 including generating local timing signals at each of the auxiliary control units (12) which are synchronised with the local timing signals of other auxiliary control units, and generating the local control signals synchronously with the respective local timing signals.

12. A method according to claim 10 or claim 11 characterised in that the master programming signals are generated in accordance with a blast pattern which is configured on a computer (44).

13. A method according to claim 12 including laying out the blast pattern graphically on a display (46) of the computer (44).

14. A method according to any one of claims 10 to 13 including programming each delay device (16) with a respective delay time.

15. A method according to claim 14 characterised in that the delay times for respective delay devices (16) are programmed automatically, using a stored timing pattern.

16. A method according to claim 14 or claim 15 characterised in that the programmed delay times are ad-

justed in accordance with a chosen blast parameter to optimise that parameter.

17. A method according to claim 16 characterised in that the chosen blast parameter is related to optimal rock fragmentation, reduced ground vibration, or reduced air blast levels.

18. A method according to claim 12 characterised in that the master programming signals transmitted to respective different auxiliary control units (12) contain information which is adapted to respective blasting zones.

Patentansprüche

1. Sprengsteuervorrichtung zum Aktivieren einer Vielzahl von Gruppen elektrischer Zünder, die nach vorher festgelegten Zeitverzögerungen ausgelöst werden; inbegriffen eine Hauptsteuereinheit (10) und eine Vielzahl von Hilfssteuereinheiten (12), die jeweils eine zugeordnete Gruppe von entfernt angeordneten elektronischen Verzögerungsvorrichtungen (16) steuern, die den jeweils zugehörigen elektrisch ausgelösten Zündern zugeordnet sind, **dadurch gekennzeichnet,** daß die Hauptsteuereinheit beinhaltet:

Hauptprozessormittel (40) zur Erzeugung von Hauptprogrammiersignalen entsprechend einer Aktivierungssequenz für die Zünder jeder Gruppe elektrisch auslösbarer Zünder; eine Vielzahl von Kommunikationsschnittstellen (48) zur Übertragung der Hauptprogrammiersignale an die jeweiligen Hilfssteuereinheiten; Referenztaktgebermittel (42) zur Erzeugung eines Haupttaktsignals zur Übertragung an die jeweiligen Hilfssteuereinheiten, und Controllermittel zur Erzeugung von Hauptsteuersignalen entsprechend einer Auslöseanweisung für die elektrischen Verzögerungsvorrichtungen; weiterhin dadurch gekennzeichnet, daß jede Hilfssteuereinheit an die Hauptsteuereinheit angeschlossen werden kann und beinhaltet:

interne Prozessormittel (20) zum Empfang der Hauptprogrammiersignale zur Erzeugung interner Programmiersignale für die Programmierung der Funktion der jeweiligen Gruppe der entfernt angeordneten Verzögerungsvorrichtungen entsprechend der Auslösesequenz; Synchronisiermittel (60) zur Erzeugung interner Taktsignale synchron zum Haupttaktsignal; Stromversorgungsmittel (50, 54) geeignet zur Versorgung der elektrischen Verzögerungsvorrichtungen sowie der zugeordneten elektrisch ausgelösten Zünder mit Strom; und interne Steuermittel (20) zur Erzeugung interner Steuersignale auf Grundlage der Hauptsteuersignale, die mit den internen Steuersignalen anderer Hilfssteuereinheiten synchronisiert werden, wenn die Vorrichtung in Betrieb ist, um auf diese Weise die Funktion der elektrischen Verzögerungsvorrichtungen der jeweils zugeordneten Gruppe elektrisch ausgelöster Zünder zu initiieren, so daß die Auslösesequenzen der elektrisch ausgelösten Zünder jeder Gruppe elektrisch ausgelöster Zünder synchronisiert werden.

2. Vorrichtung nach Anspruch 1, **dadurch gekennzeichnet**, daß die elektrisch ausgelösten Zünder jeweils mit einer elektrischen Verzögerungsvorrichtung (16) verbunden sind.

3. Vorrichtung nach Anspruch 2, **dadurch gekennzeichnet**, daß die Hauptsteuereinheit (10) Hauptprozessormittel (40) zur Erzeugung eines Sprengbildes einschließlich der Auslösesequenzen für die Zünder innerhalb jeder Gruppe von Zündern beinhaltet;

4. Vorrichtung nach einem der Ansprüche 1 bis 3, **dadurch gekennzeichnet**, daß jede Hilfssteuereinheit (12) eine Hilfskommunikationsschnittstelle (22) zum Empfang der Hauptsteuersignale von der zentralen Steuereinheit (10) und zur Übertragung der den Funktionsstatus der Hilfssteuereinheit darstellenden Daten an die Hauptsteuereinheit beinhaltet.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, **dadurch gekennzeichnet**, daß das Synchronisationsmittel (60) jeder Hilfssteuereinheit (12) einen internen Oszillator (24) zur Erzeugung eines primären Taktsignals, dessen Frequenz größer ist als die des Haupttaktsignals, Frequenzeinstellmittel (26, 28, 30) zur schrittweisen Erhöhung oder Verringerung der Frequenz des primären internen Taktsignals in Reaktion auf Korrektursignale, Frequenzteilermittel (32) zur Verringerung der Frequenz des primären internen Taktsignals auf eine Frequenz, die derjenigen des Haupttaktsignals angenähert ist, und Vergleichsmittel (34, 36) zum Vergleich des Ausgangs des Frequenzteilers mit dem Haupttaktsignal und zur Erzeugung von Korrektursignalen beinhaltet, die an das Frequenzeinstellmittel übermittelt werden, so daß die Ausgangsfrequenz des Frequenzteilers sich der Frequenz des Haupttaktsignals annähert.

6. Vorrichtung nach Anspruch 5, **dadurch gekennzeichnet**, daß das Frequenzeinstellmittel (26, 28, 30) einen Multiplexer (30), eine Impulsadditionsschaltung (26), die zwischen dem internen Oszillator und einem ersten Eingang (A) des Multiplexers geschaltet ist, und eine Impulssubtraktionsschaltung (28) beinhaltet, die zwischen dem internen Oszillator und einem zweiten Eingang (C) des Multiplexers geschaltet ist, wobei der Ausgang des internen Oszillators direkt mit dem dritten Eingang (B)

des Multiplexers verbunden ist, und wobei ein erster, zweiter oder dritter Eingang des Multiplexers entsprechend den Korrektursignalen ausgewählt wird, um die Frequenz des primären internen Taktsignals schrittweise an den Ausgang des Multiplexers anzupassen.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, **dadurch gekennzeichnet**, daß das Synchronisationsmittel (60) jeder Hilfssteuereinheit (12) die Erzeugung der mit dem Haupttaktsignal synchronisierten internen Taktsignale unabhängig vom Haupttaktsignal und über einen festgelegten Zeitraum vor Auslösung der jeweiligen elektrisch ausgelösten Zünder übernimmt.

8. Vorrichtung nach einem der Ansprüche 1 bis 7, **dadurch gekennzeichnet,** daß die Hauptsteuereinheit (10) für den Empfang der von einem Hilfscomputer (44) stammenden Daten entsprechend der Auslösesequenz der Zünder aller Gruppen elektrisch ausgelöster Zünder sowie für die Übertragung von Daten entsprechend der Auslösesequenz der Zünder aller Gruppen elektrisch ausgelöster Zünder an die jeweilige Hilfssteuereinheit (12) eingerichtet ist.

9. Vorrichtung nach Anspruch 8, **dadurch gekennzeichnet**, daß die Hauptsteuereinheit (10) für den Empfang von aus jeder einzelnen Hilfssteuereinheit (12) stammenden Daten entsprechend des Funktionsstatus der Hilfssteuereinheit (12) sowie für die Übertragung der empfangenen Daten an den Hilfscomputer (44) eingerichtet ist, so daß der Status jeder Hilfssteuereinheit zentral überwacht werden kann.

10. Verfahren zur Auslösung einer Vielzahl von Gruppen elektrischer Zünder, wobei jeder Zünder eine zugehörige elektrische Verzögerungsschaltung hat und die Auslösung nach bestimmten Zeitverzögerungsintervallen erfolgt; **dadurch gekennzeichnet**, daß das Verfahren beinhaltet:

die Übertragung von Hauptprogrammiersignalen entsprechend einer Auslösesequenz für die elektrischen Zünder jeder Gruppe elektrischer Zünder von einer Hauptsteuereinheit (10) an jede einzelne einer Vielzahl von Hilfssteuereinheiten (12);

die Erzeugung interner Programmiersignale in jeder Hilfssteuereinheit (12) auf Basis der Hauptprogrammiersignale sowie die Übertragung der internen Programmiersignale an die elektrischen Verzögerungsvorrichtungen (16) der jeweiligen Gruppen elektrisch ausgelöster Zünder, wodurch die Funktion jeder einzelnen elektrischen Verzögerungseinrichtung und des zugehörigen Zünders programmiert wird;

die Erzeugung von Hauptsteuersignalen in der Hauptsteuereinheit (10) entsprechend der Auslöseanweisung für die elektrischen Verzögerungsvorrichtungen (16), die den jeweiligen Zündern jeder Gruppe elektrischer Zünder zugeordnet sind, sowie die Übertragung der entsprechenden Hauptsteuersignale an die einzelnen Hilfssteuereinheiten (12);

die Erzeugung von Haupttaktsignalen in der Hauptsteuereinheit (10) und die Übertragung der Haupttaktsignale an jede einzelne Hilfssteuereinheit (12);

die Erzeugung interner Steuersignale in jeder einzelnen Hilfssteuereinheit (12) auf Basis der Hauptsteuersignale und der Haupttaktsignale, wobei die internen Steuersignale jeder einzelnen Hilfssteuereinheit miteinander synchronisiert werden, um die Funktion der elektrischen Verzögerungsvorrichtungen (16) der jeweiligen Gruppe elektrischer Zünder zu initiieren; und

die Versorgung der Verzögerungsvorrichtungen (16) und ihrer zugehörigen Zünder mit Strom zur Auslösung der Zünder, so daß die Auslösesequenzen der elektrischen Zünder jeder Gruppe elektrischer Zünder synchronisiert werden.

11. Verfahren nach Anspruch 10, inbegriffen die Erzeugung interner Taktsignale in jeder der Hilfssteuereinheit (12), die mit den internen Taktsignalen anderer Hilfssteuereinheiten synchronisiert werden, sowie die Erzeugung der internen Steuersignale synchron zu den jeweiligen internen Taktsignalen.

12. Verfahren nach Anspruch 10 oder 11, **dadurch gekennzeichnet**, daß die Hauptprogrammiersignale entsprechend des mit Hilfe eines Computers (44) konfigurierten Sprengbildes erzeugt werden.

13. Verfahren nach Anspruch 12, inbegriffen der grafische Entwurf des Sprengbildes auf dem Bildschirm (46) des Computers (44).

14. Verfahren nach einem der Ansprüche 10 bis 13, inbegriffen die Programmierung jeder einzelnen Verzögerungsvorrichtung (16) mit der entsprechenden Verzögerungszeit.

15. Verfahren nach Anspruch 14, **dadurch gekennzeichnet**, daß die Verzögerungszeiten für die einzelnen Verzögerungsvorrichtungen (16) automatisch anhand eines gespeicherten Zeitmusters pro-

grammiert werden.

16. Verfahren nach Anspruch 14 oder 15, **dadurch gekennzeichnet**, daß die programmierten Verzögerungszeiten entsprechend einem gewählten Sprengparameter korrigiert werden, um diesen Parameter zu optimieren.

17. Verfahren nach Anspruch 16, **dadurch gekennzeichnet**, daß der Sprengparameter entsprechend den Vorgaben einer optimalen Gesteinszertrümmerung, reduzierter Bodenerschütterungen oder verringerter Druckluftwellen gewählt wird.

18. Verfahren nach Anspruch 12, **dadurch gekennzeichnet**, daß die Hauptprogrammiersignale, die an die einzelnen Hilfssteuereinheiten (12) übertragen werden, Informationen enthalten, die auf die einzelnen Sprengzonen abgestimmt sind.

Revendications

1. Appareil de commande d'explosion, pour activer plusieurs groupes de détonateurs électriquement activés après des durées respectives de temporisation prédéterminées, comportant une unité de commande maître (10) et plusieurs unités de commande auxiliaires (12), chacune adaptée pour commander un groupe respectif de dispositifs électriques de temporisation éloignés (16) qui sont associés à des détonateurs électriquement activés correspondants, caractérisé en ce que l'unité de commande maître comporte:

   un moyen à processeur maître (40) adapté pour produire des signaux de programmation maîtres qui correspondent à une séquence d'activation des détonateurs de chaque groupe de détonateurs électriquement activés, plusieurs interfaces de communication (48) pour transmettre les signaux de programmation maîtres à des unités de commande auxiliaires respectives, un moyen (42) de synchronisation de référence pour produire un signal de synchronisation maître à transmettre à chaque unité auxiliaire de commande, et moyen de commande pour produire des signaux de commande maîtres correspondant à une instruction d'amorçage des dispositifs électriques de temporisation; et en outre caractérisé en ce que chaque unité de commande auxiliaire peut être reliée à l'unité de commande maître et comporte:

   des moyens locaux à processeur (20) répondant aux signaux de programmation maîtres pour produire des signaux de programmation locaux en vue de programmer le fonctionnement du groupe respectif de dispositifs électriques de temporisation éloignés en accord avec la séquence d'activation, un moyen de synchronisation (60) pour produire des signaux de synchronisation locaux en synchronisme avec le signal de synchronisation maître, des moyens d'alimentation en énergie (50, 54) adaptés pour foumir de l'énergie électrique aux dispositifs électriques de temporisation et aux détonateurs électriquement activés correspondants, et des moyens de commande (20) locaux pour produire à partir des signaux de commande maîtres des signaux de commande locaux qui sont synchronisés avec les signaux de commande locaux d'autres unités de commande auxiliaires lorsque l'appareil est en utilisation, pour amorcer le fonctionnement des dispositifs électriques de temporisation du groupe respectif de détonateurs électriquement activés, de telle sorte que les séquences d'activation des détonateurs électriquement activés de chaque groupe de détonateurs électriquement activés soient synchronisées.

2. Appareil selon la revendication 1, caractérisé en ce que les détonateurs électriquement activés présentent chacun un dispositif électrique de temporisation (16) associé.

3. Appareil selon la revendication 2, caractérisé en ce que l'unité de commande maître (10) comprend un moyen à processeur maître (40) pour produire un motif d'explosion comprenant des séquences d'activation pour les détonateurs de chaque groupe de détonateurs.

4. Appareil selon l'une quelconque des revendications 1 à 3, caractérisé en ce que chaque unité de commande auxiliaire (12) comporte un interface de communication auxiliaire (22) pour recevoir les signaux de commande maîtres de l'unité centrale de commande (10) et pour transmettre à l'unité de commande maître des données représentatives de l'état de fonctionnement de l'unité de commande auxiliaire.

5. Appareil selon l'une quelconque des revendications 1 à 4, caractérisé en ce que le moyen de synchronisation (60) de chaque unité de commande auxiliaire (12) comporte un oscillateur local (24) pour produire un signal d'horloge locale primaire à une fréquence supérieure à celle du signal de synchronisation maître, des moyens d'ajustement en fréquence (26, 28, 30) pour augmenter ou diminuer par incréments la fréquence du signal d'horloge locale primaire en réponse à des signaux de correction, un moyen à diviseur de fréquence (32) pour réduire la fréquence du signal d'horloge locale primaire jusqu'à une fréquence proche de celle du signal de temporisation maître, et des moyens à comparateur (34, 36) pour comparer la sortie du diviseur de fréquence au signal de synchronisation maître et pour produire des signaux de correction qui sont

appliqués sur les moyens d'ajustement en fréquence de telle sorte que la fréquence de sortie du diviseur de fréquence s'approche de celle du signal de synchronisation maître.

6. Appareil selon la revendication 5, caractérisé en ce que les moyens d'ajustement en fréquence (26, 28, 30) comprennent un multiplexeur (30), un circuit additionneur d'impulsions (26) connecté entre l'oscillateur local et une première entrée (A) du multiplexeur, et un circuit soustracteur d'impulsions (28) connecté entre l'oscillateur local et une deuxième entrée (C) du multiplexeur, la sortie de l'oscillateur local étant reliée directement à une troisième entrée (B) du multiplexeur, l'une parmi la première, la deuxième et la troisième entrée du multiplexeur étant choisie en réponse aux signaux de correction, pour ajuster par incréments la fréquence du signal primaire d'horloge locale sur une sortie du multiplexeur.

7. Appareil selon l'une quelconque des revendications 1 à 6, caractérisé en ce que le moyen de synchronisation (60) de chaque unité de commande auxiliaire (12) est agencé pour produire les signaux de synchronisation locaux qui ont été synchronisés sur le signal de synchronisation maître, et ce indépendamment du signal de synchronisation maître, pendant une durée prédéterminée antérieure à l'activation des détonateurs électriquement activés respectifs.

8. Appareil selon l'une quelconque des revendications 1 à 7, caractérisé en ce que l'unité de commande maître (10) est adaptée pour recevoir d'un calculateur auxiliaire (44) des données qui correspondent à la séquence d'activation des détonateurs de tous les groupes de détonateurs électriquement activés, et pour transférer les données correspondant à la séquence d'activation pour les détonateurs de chaque groupe de détonateurs électriquement activés, à l'unité de commande auxiliaire respective (12).

9. Appareil selon la revendication 8, caractérisé en ce que l'unité de commande maître (10) est adaptée pour recevoir de chaque unité de commande auxiliaire (12) des données qui correspondent à leur état de fonctionnement, et pour transférer les données reçues vers le calculateur auxiliaire (44), de manière à pouvoir surveiller centralement l'état de chaque unité de commande auxiliaire.

10. Procédé d'activation, après des temporisations respectives prédéterminées, de plusieurs groupes de détonateurs électriques qui présentent chacun un dispositif électrique de temporisation associé, caractérisé en ce que le procédé comporte les étapes consistant à:

transmettre des signaux de programmation maîtres correspondant à une séquence d'activation des détonateurs électriques de chaque groupe de détonateurs électriques, depuis une unité de commande maître (10) jusque chacune parmi plusieurs unités de commande auxiliaires (12);
à partir des signaux de programmation maîtres, produire des signaux de programmation locaux sur chaque unité de commande auxiliaire (12), et transmettre les signaux de programmation locaux aux dispositifs électriques de temporisation (16) des groupes respectifs de détonateurs électriques, pour ainsi programmer le fonctionnement de chaque dispositif électrique de temporisation et de son détonateur associé;
sur l'unité de commande maître (10), produire des signaux de commande maîtres qui correspondent à une instruction d'amorçage des dispositifs électriques de temporisation (16) associés aux détonateurs respectifs de chaque groupe de détonateurs électriques, et transmettre les signaux de commande maîtres respectifs à chaque unité de commande auxiliaire (12);
sur l'unité de commande maître (10), produire des signaux de synchronisation maîtres et transmettre les signaux de synchronisation maîtres à chaque unité de commande auxiliaire (12);
à partir des signaux de commande maîtres et des signaux de synchronisation maîtres, produire des signaux de commande locaux sur chaque unité de commande auxiliaire (12), les signaux de commande locaux de chaque unité de commande auxiliaire étant synchronisés les uns avec les autres, pour amorcer le fonctionnement des dispositifs électriques de temporisation (16) des groupes respectifs de détonateurs électriques; et
alimenter en énergie les dispositifs de temporisation (16) et leurs détonateurs associés, pour activer les détonateurs de telle sorte que les séquences d'activation des détonateurs électriques de chaque groupe de détonateurs électriques soient synchronisées.

11. Procédé selon la revendication 10, comportant, sur chacune des unités de commande auxiliaires (12), la production de signaux de synchronisation locaux qui sont synchronisés sur les signaux de synchronisation locaux d'autres unités de commande auxiliaires, et la production des signaux de commande locaux en synchronisme avec les signaux de synchronisation locaux respectifs.

12. Procédé selon la revendication 10 ou la revendication 11, caractérisé en ce que les signaux de pro-

grammation maîtres sont produits en accord avec un motif d'explosion qui est configuré sur un calculateur (44).

13. Procédé selon la revendication 12, qui comporte l'affichage graphique du motif d'explosion sur un dispositif d'affichage (46) du calculateur (44).

14. Procédé selon l'une quelconque des revendications 10 à 13, comportant la programmation de chaque dispositif de temporisation (16) avec une durée respective de temporisation.

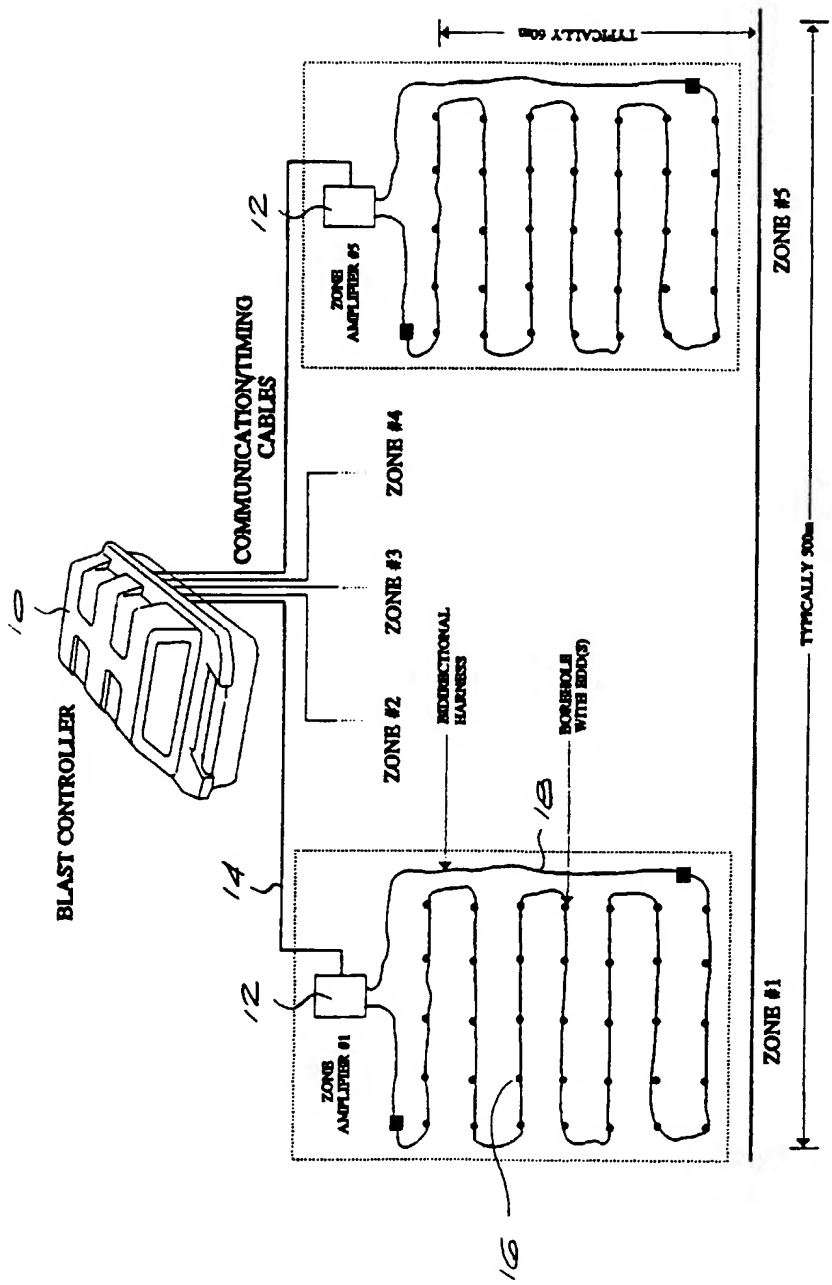
15. Procédé selon la revendication 14, caractérisé en ce que les durées de temporisation des dispositifs de temporisation (16) respectifs sont programmées automatiquement en recourant à un motif de synchronisation conservé en mémoire.

16. Procédé selon la revendication 14 ou la revendication 15, caractérisé en ce que les durées programmées de temporisation sont ajustées en accord avec un paramètre d'explosion choisi, en vue d'optimiser ce paramètre.

17. Procédé selon la revendication 16, caractérisé en ce que le paramètre d'explosion choisi est relié à une fragmentation optimale de la roche, une vibration réduite du sol et un niveau réduit d'explosion dans l'air.

18. Procédé selon la revendication 12, caractérisé en ce que les signaux de programmation maîtres transmis vers les différentes unités de commande auxiliaires (12) respectives contiennent des informations qui sont adaptées aux zones d'explosion respectives.

FIG 1


BLAST CONTROLLER
10
COMMUNICATION/TIMING CABLES
12
ZONE AMPLIFIER #5
ZONE #5
ZONE #4
ZONE #3
ZONE #2
ZONE #1
BIDIRECTIONAL HARNESS
BOREHOLE WITH EDCP
14
18
16
TYPICALLY 500m

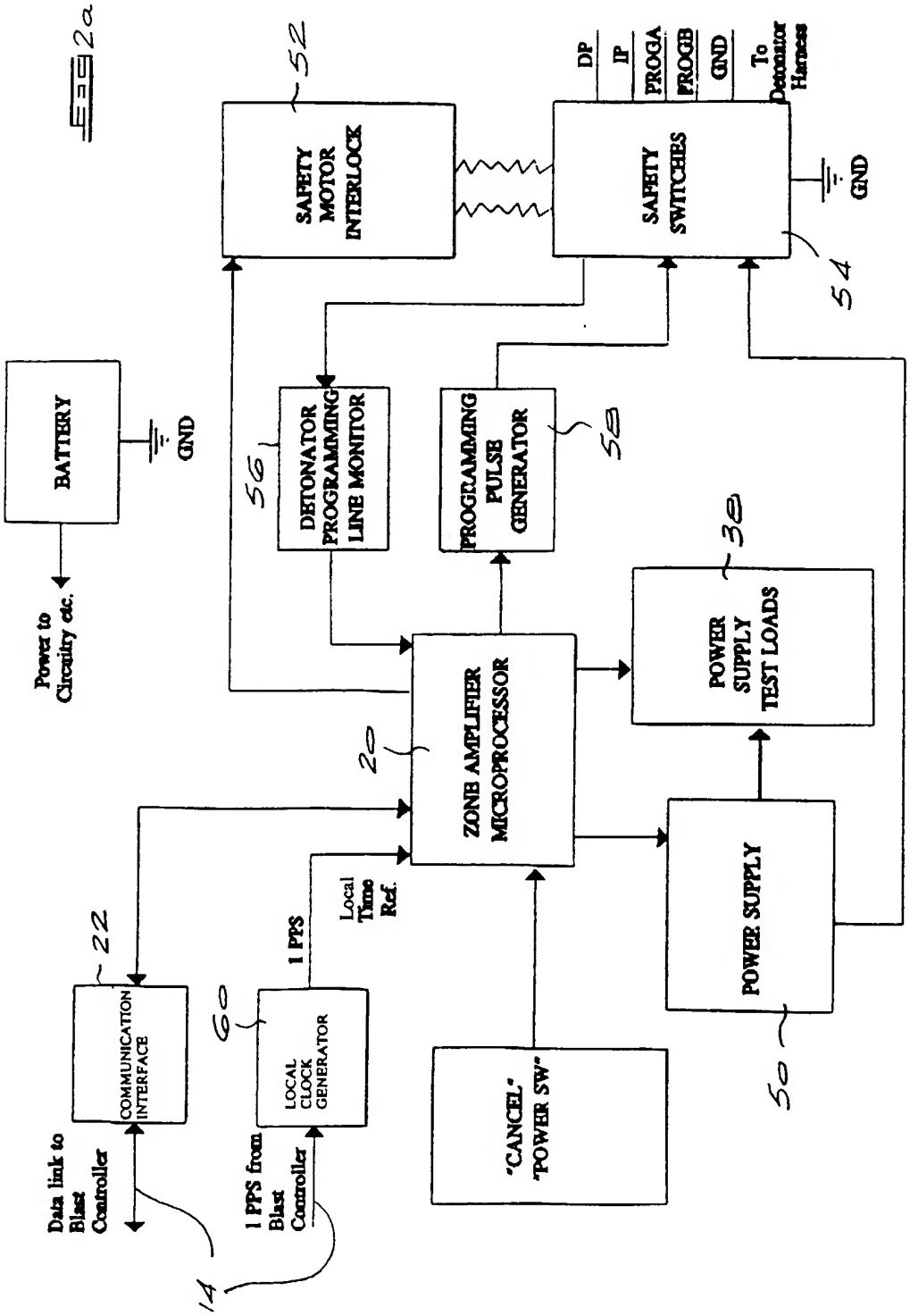


Fig 2a
SAFETY MOTOR INTERLOCK
52
SAFETY SWITCHES
54
DP
IP
PROGA
PROGB
GND
To Detonator Harness
GND
BATTERY
GND
Power to Circuitry etc.
DETONATOR PROGRAMMING LINE MONITOR
56
PROGRAMMING PULSE GENERATOR
58
ZONE AMPLIFIER MICROPROCESSOR
20
POWER SUPPLY TEST LOADS
30
POWER SUPPLY
50
"CANCEL" "POWER SW"
COMMUNICATION INTERFACE
22
LOCAL CLOCK GENERATOR
60
1 PPS
Local Time Ref.
Data link to Blast Controller
1 PPS from Blast Controller
14

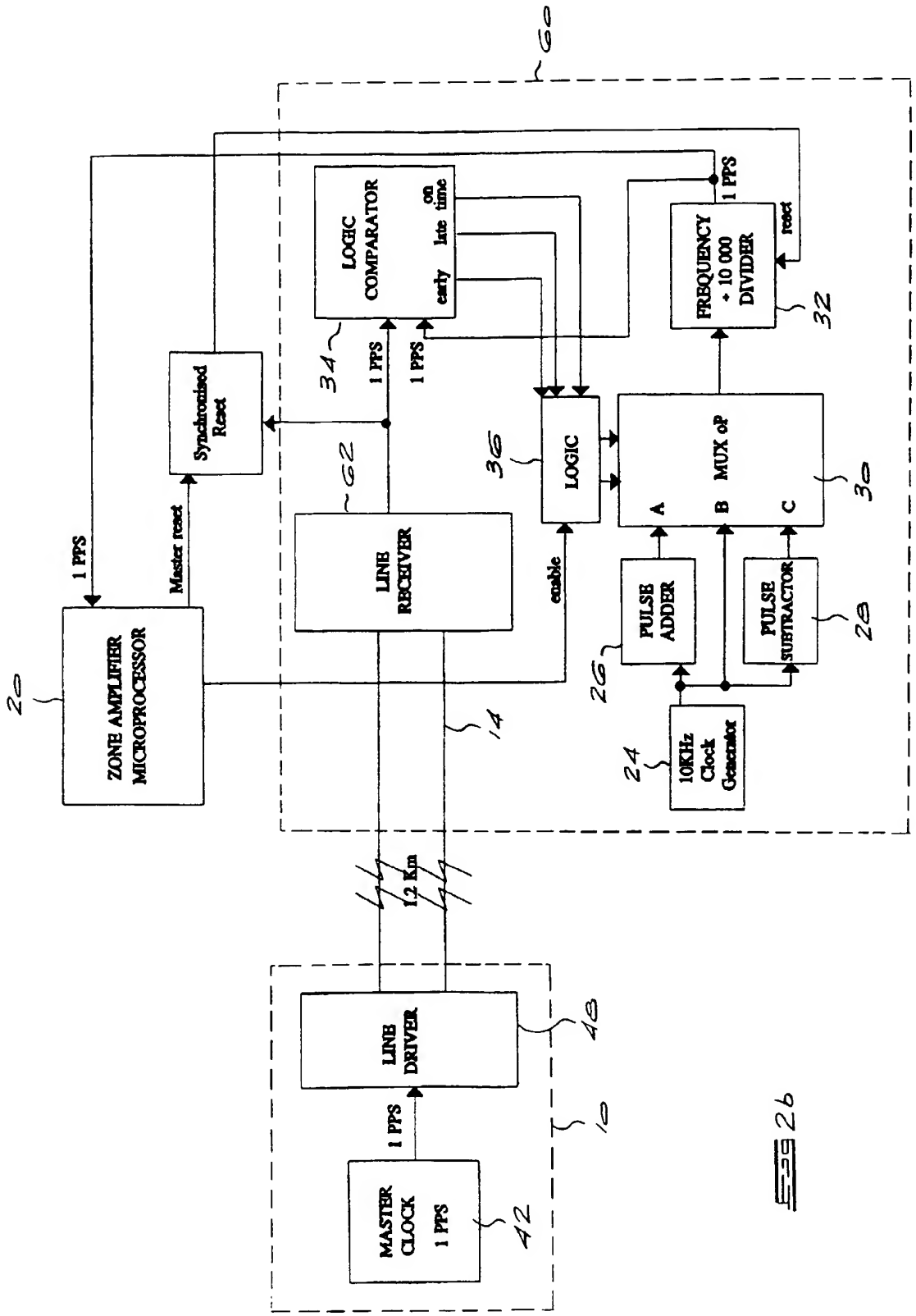

60
LOGIC COMPARATOR
on time
late
early
34
1 PPS
1 PPS
FREQUENCY ÷ 10 000 DIVIDER
1 PPS
reset
32
Synchronised Reset
62
LOGIC
36
MUX oP
A
B
C
30
LINE RECEIVER
enable
PULSE ADDER
26
PULSE SUBTRACTOR
28
1 PPS
Master reset
ZONE AMPLIFIER MICROPROCESSOR
20
14
10KHz Clock Generator
24
1.2 Km
LINE DRIVER
48
1 PPS
MASTER CLOCK 1 PPS
42
10

FIG 26

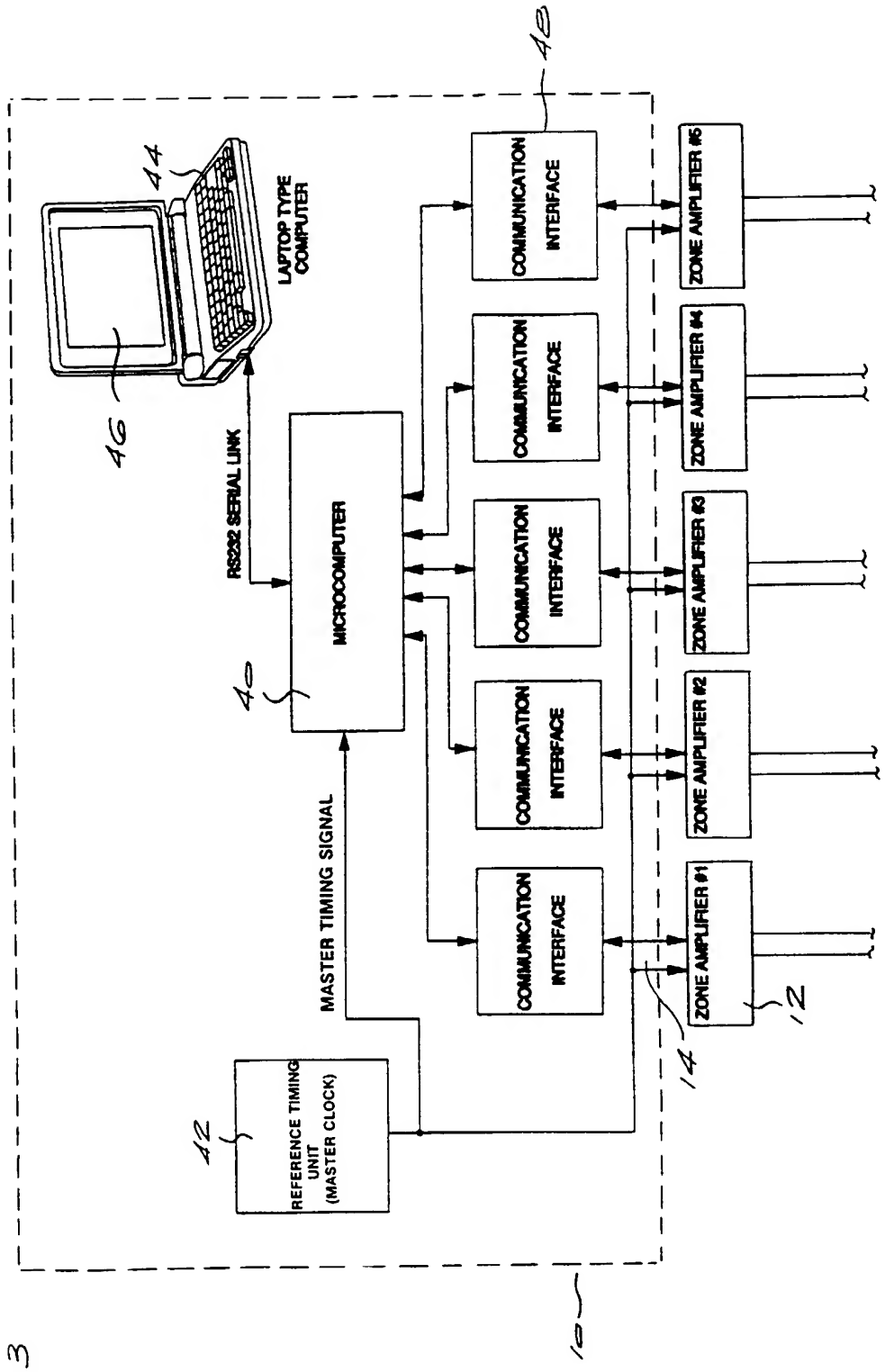

LAPTOP TYPE COMPUTER
RS232 SERIAL LINK
MICROCOMPUTER
MASTER TIMING SIGNAL
REFERENCE TIMING UNIT (MASTER CLOCK)
COMMUNICATION INTERFACE
COMMUNICATION INTERFACE
COMMUNICATION INTERFACE
COMMUNICATION INTERFACE
COMMUNICATION INTERFACE
ZONE AMPLIFIER #5
ZONE AMPLIFIER #4
ZONE AMPLIFIER #3
ZONE AMPLIFIER #2
ZONE AMPLIFIER #1
44
46
40
42
48
12
14
10

FIG 3

Fig 4

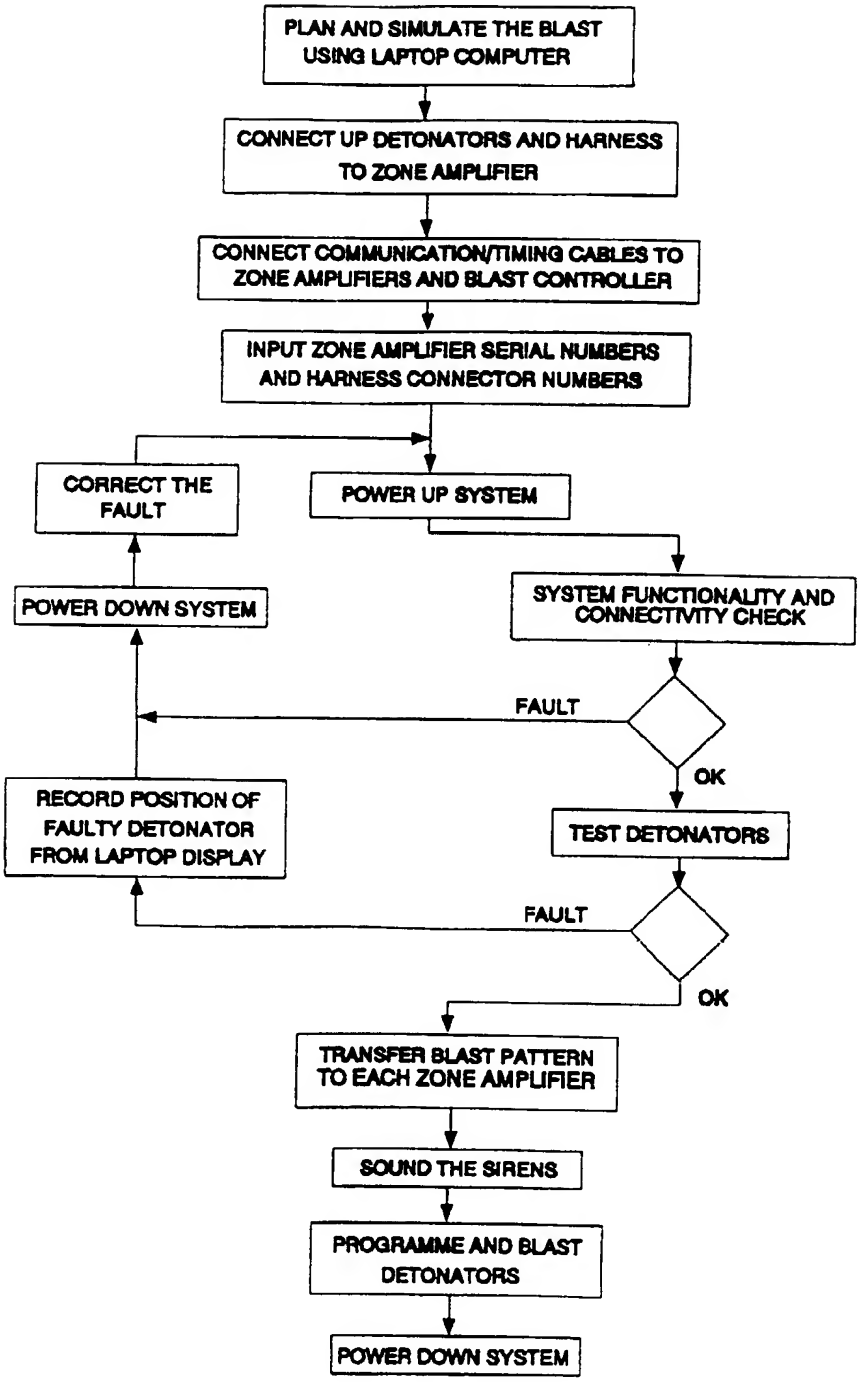

PLAN AND SIMULATE THE BLAST USING LAPTOP COMPUTER
CONNECT UP DETONATORS AND HARNESS TO ZONE AMPLIFIER
CONNECT COMMUNICATION/TIMING CABLES TO ZONE AMPLIFIERS AND BLAST CONTROLLER
INPUT ZONE AMPLIFIER SERIAL NUMBERS AND HARNESS CONNECTOR NUMBERS
CORRECT THE FAULT
POWER UP SYSTEM
POWER DOWN SYSTEM
SYSTEM FUNCTIONALITY AND CONNECTIVITY CHECK
FAULT
OK
RECORD POSITION OF FAULTY DETONATOR FROM LAPTOP DISPLAY
TEST DETONATORS
FAULT
OK
TRANSFER BLAST PATTERN TO EACH ZONE AMPLIFIER
SOUND THE SIRENS
PROGRAMME AND BLAST DETONATORS
POWER DOWN SYSTEM

FIG 5

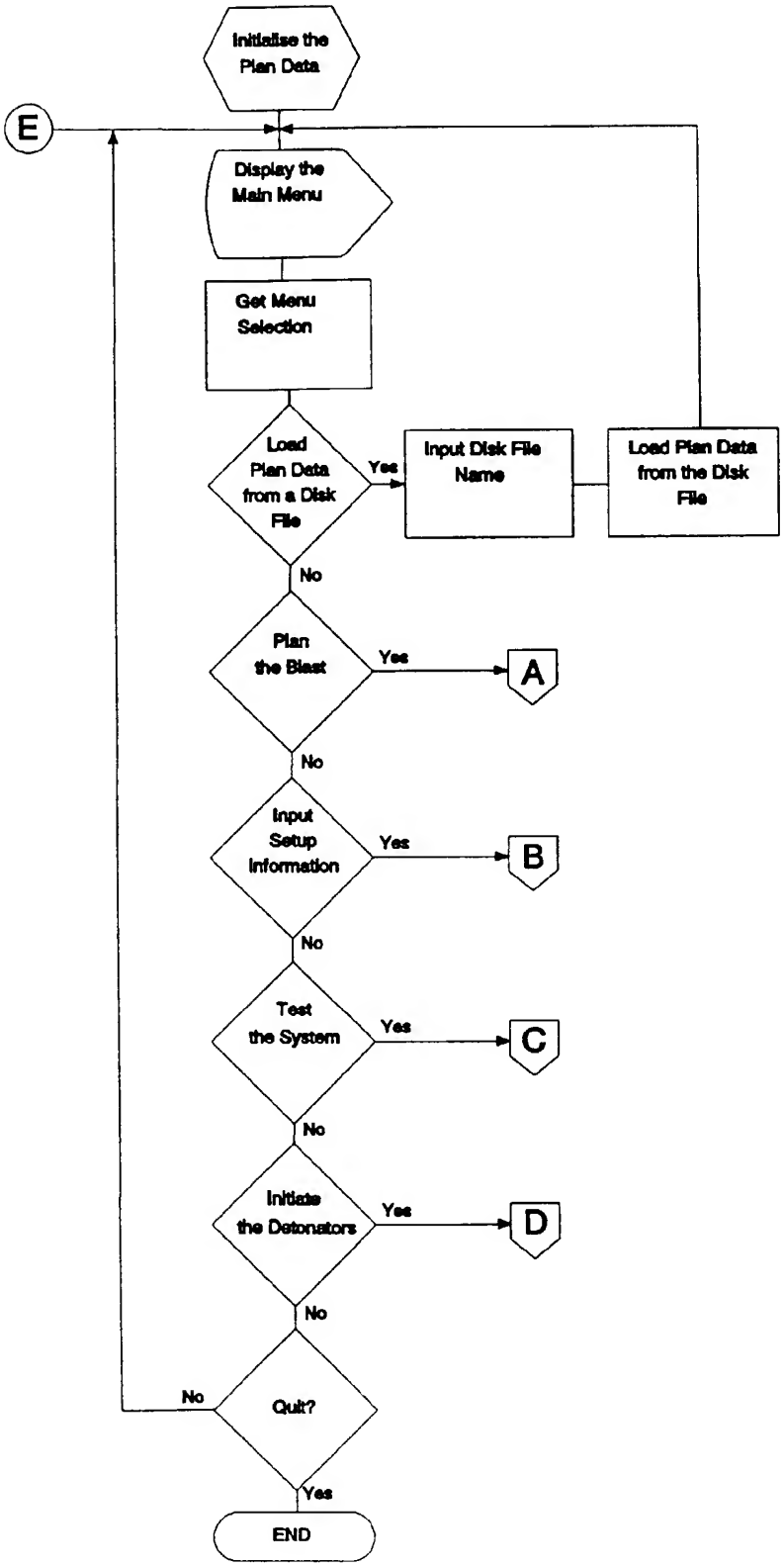

Initialise the Plan Data
E
Display the Main Menu
Get Menu Selection
Load Plan Data from a Disk File
Yes
Input Disk File Name
Load Plan Data from the Disk File
No
Plan the Blast
Yes
A
No
Input Setup Information
Yes
B
No
Test the System
Yes
C
No
Initiate the Detonators
Yes
D
No
Quit?
No
Yes
END

Fig 6a

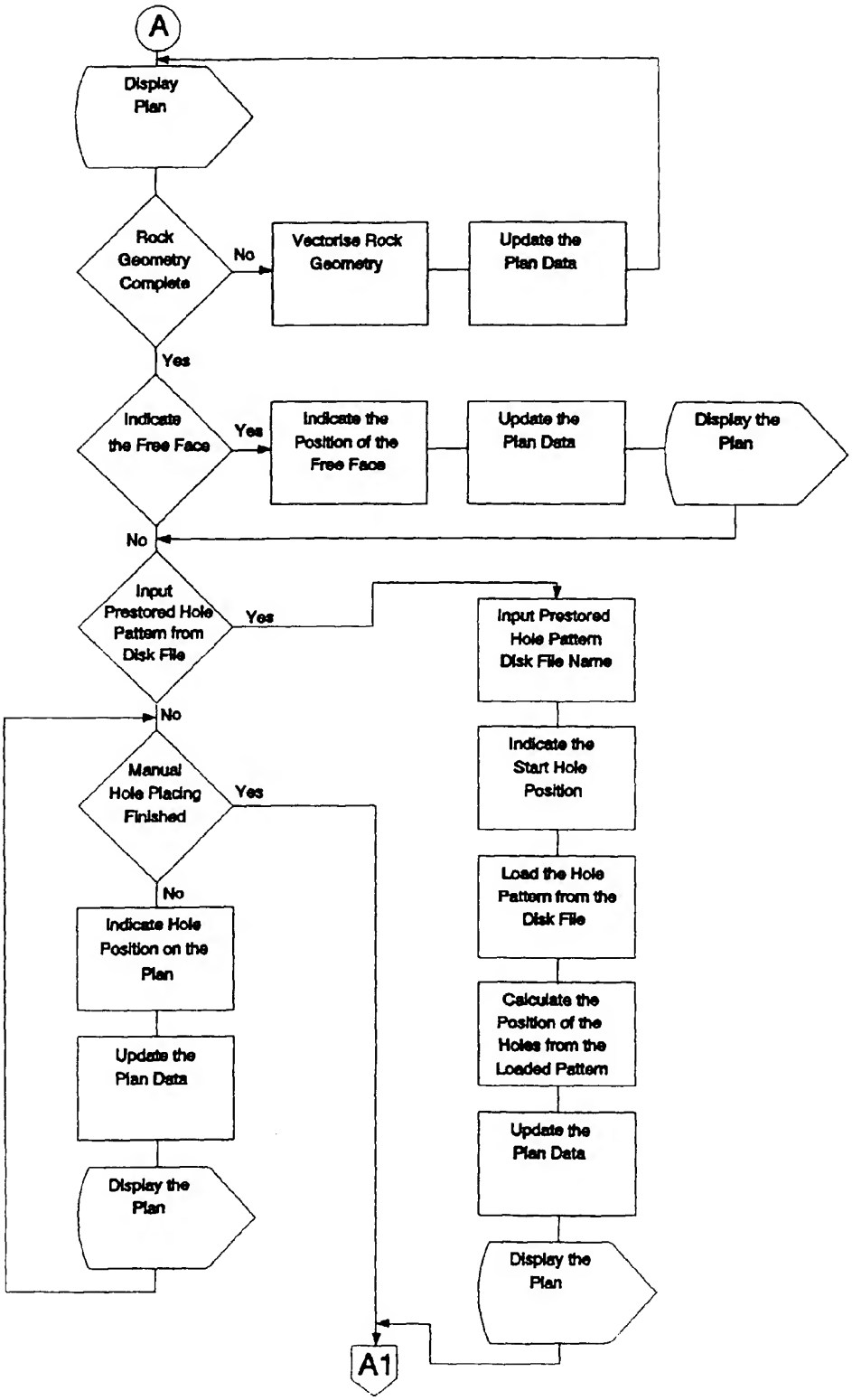

A
Display Plan
Rock Geometry Complete
No
Vectorise Rock Geometry
Update the Plan Data
Yes
Indicate the Free Face
Yes
Indicate the Position of the Free Face
Update the Plan Data
Display the Plan
No
Input Prestored Hole Pattern from Disk File
Yes
Input Prestored Hole Pattern Disk File Name
No
Manual Hole Placing Finished
Yes
Indicate the Start Hole Position
Load the Hole Pattern from the Disk File
No
Indicate Hole Position on the Plan
Calculate the Position of the Holes from the Loaded Pattern
Update the Plan Data
Update the Plan Data
Display the Plan
Display the Plan
A1

Fig 6b

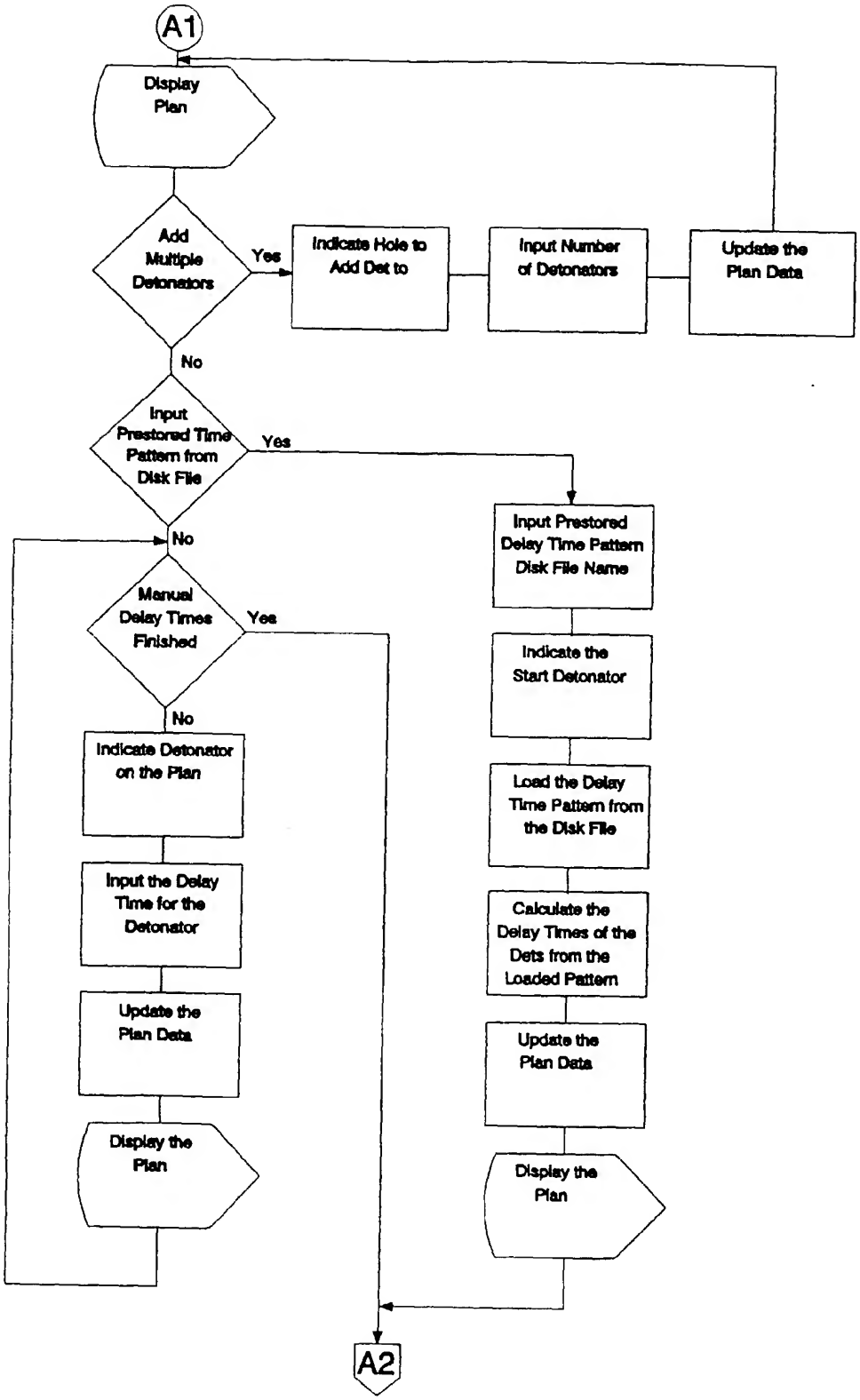

A1
Display Plan
Add Multiple Detonators
Yes
Indicate Hole to Add Det to
Input Number of Detonators
Update the Plan Data
No
Input Prestored Time Pattern from Disk File
Yes
Input Prestored Delay Time Pattern Disk File Name
Indicate the Start Detonator
Load the Delay Time Pattern from the Disk File
Calculate the Delay Times of the Dets from the Loaded Pattern
Update the Plan Data
Display the Plan
No
Manual Delay Times Finished
Yes
No
Indicate Detonator on the Plan
Input the Delay Time for the Detonator
Update the Plan Data
Display the Plan
A2

FIG 6c

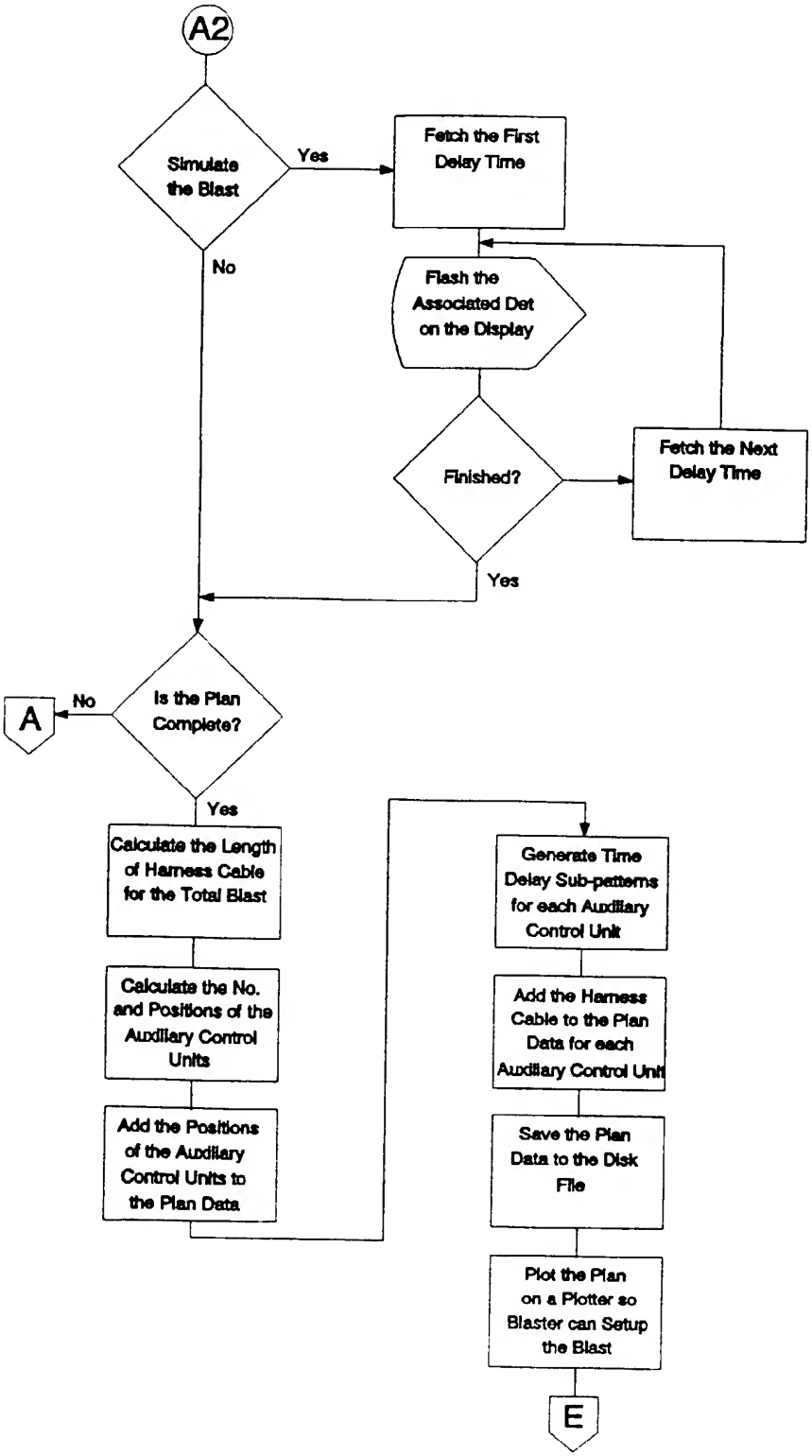

A2
Simulate the Blast
Yes
Fetch the First Delay Time
No
Flash the Associated Det on the Display
Finished?
Fetch the Next Delay Time
Yes
Is the Plan Complete?
No
A
Yes
Calculate the Length of Harness Cable for the Total Blast
Calculate the No. and Positions of the Auxiliary Control Units
Add the Positions of the Auxiliary Control Units to the Plan Data
Generate Time Delay Sub-patterns for each Auxiliary Control Unit
Add the Harness Cable to the Plan Data for each Auxiliary Control Unit
Save the Plan Data to the Disk File
Plot the Plan on a Plotter so Blaster can Setup the Blast
E

Fig 7

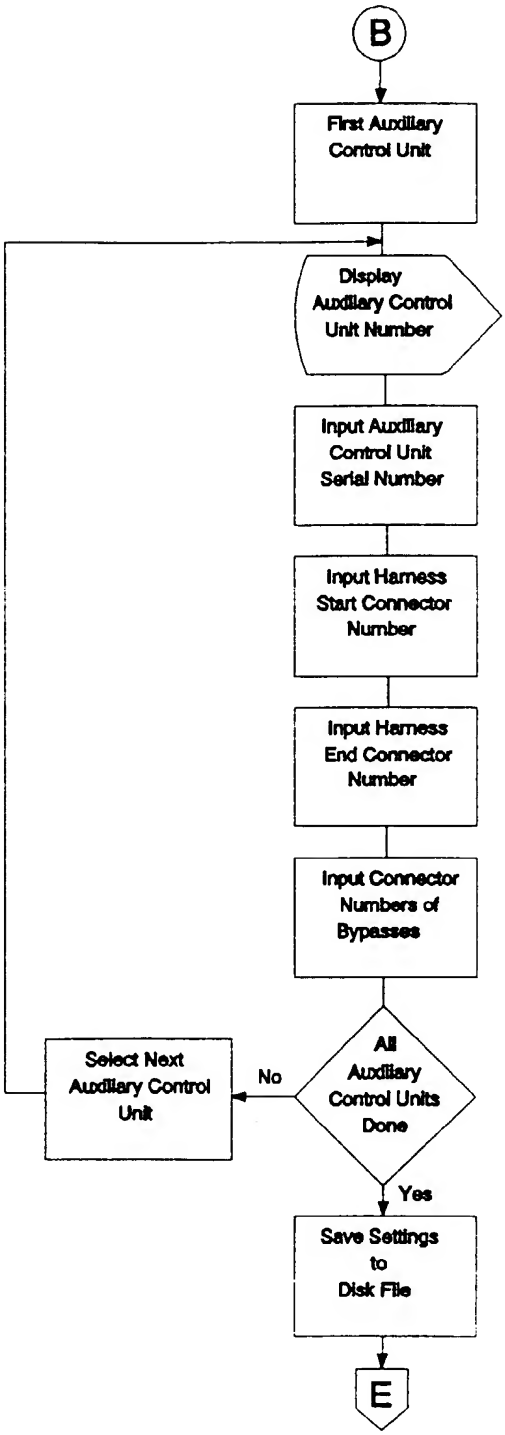

B
First Auxiliary Control Unit
Display Auxiliary Control Unit Number
Input Auxiliary Control Unit Serial Number
Input Harness Start Connector Number
Input Harness End Connector Number
Input Connector Numbers of Bypasses
All Auxiliary Control Units Done
No
Select Next Auxiliary Control Unit
Yes
Save Settings to Disk File
E

Fig 6

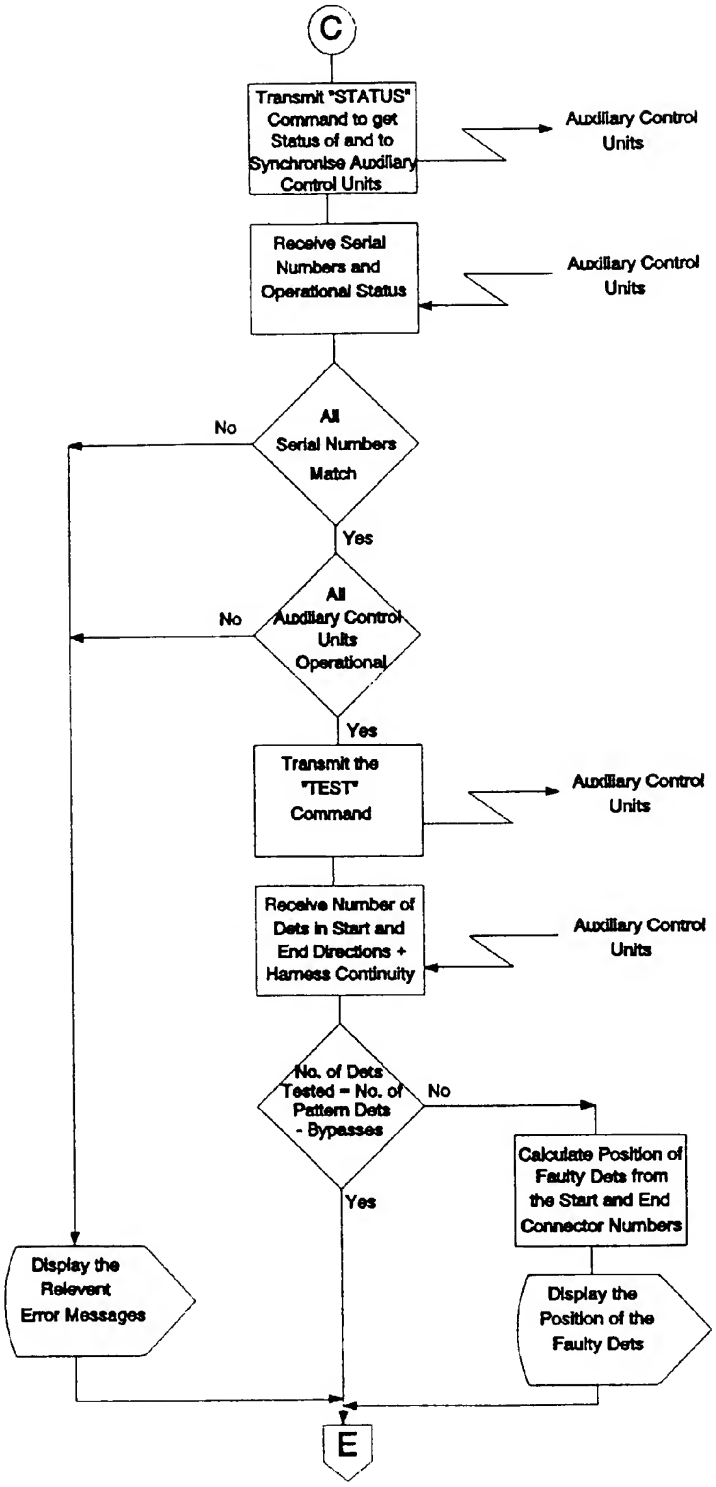
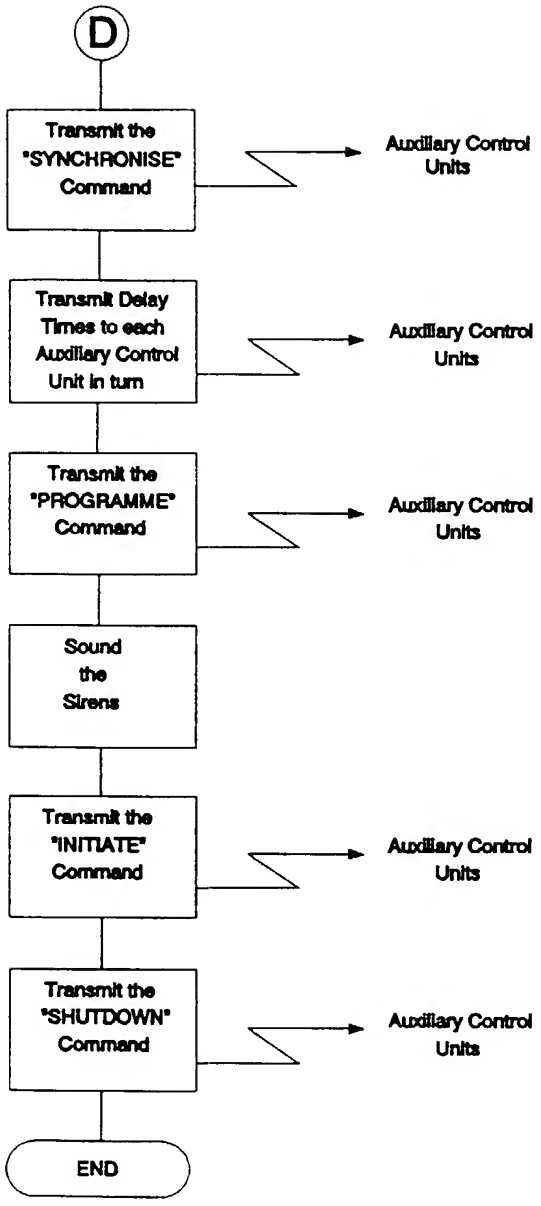
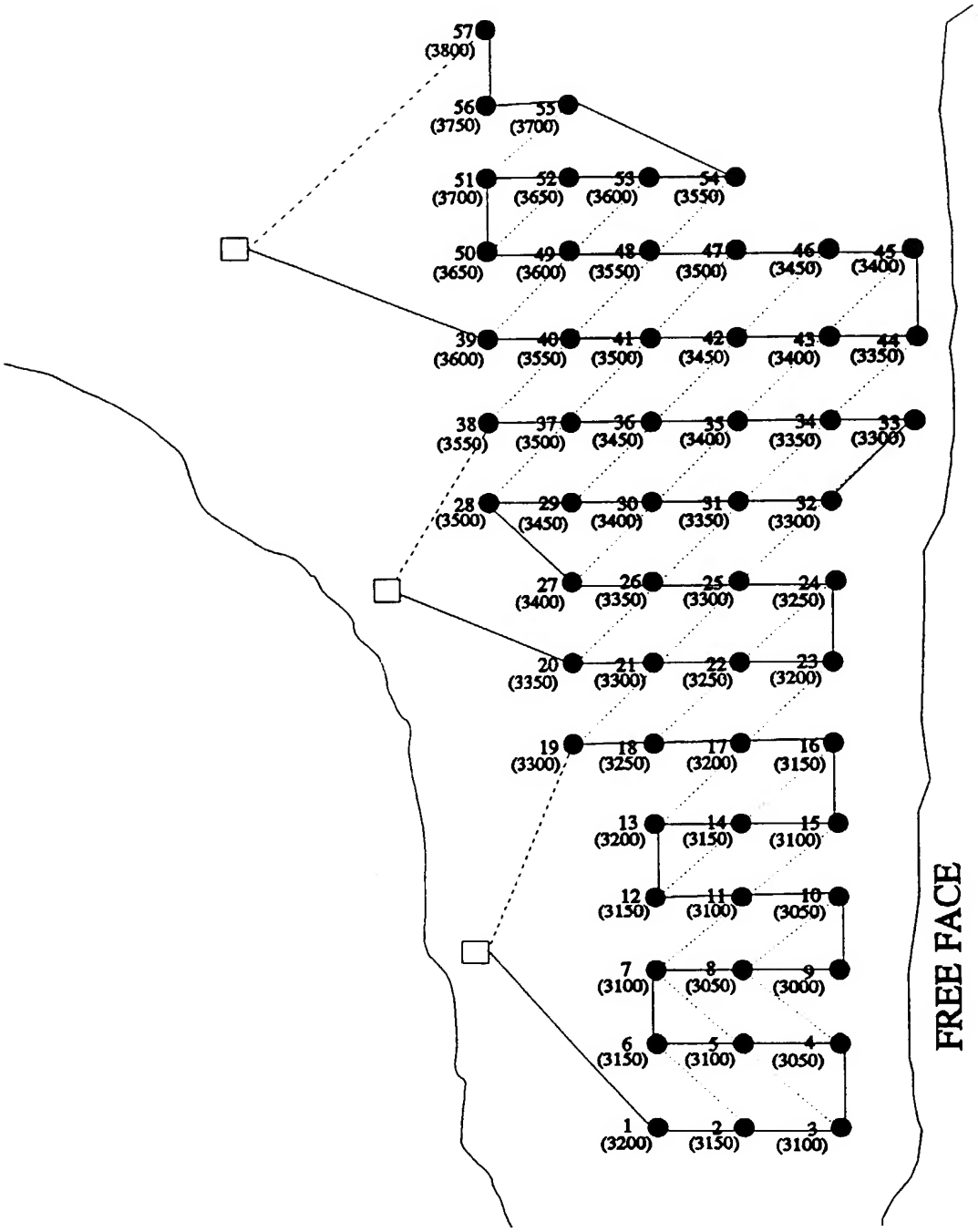

C
Transmit "STATUS" Command to get Status of and to Synchronise Auxiliary Control Units
Auxiliary Control Units
Receive Serial Numbers and Operational Status
Auxiliary Control Units
All Serial Numbers Match
No
Yes
All Auxiliary Control Units Operational
No
Yes
Transmit the "TEST" Command
Auxiliary Control Units
Receive Number of Dets in Start and End Directions + Harness Continuity
Auxiliary Control Units
No. of Dets Tested = No. of Pattern Dets - Bypasses
No
Yes
Calculate Position of Faulty Dets from the Start and End Connector Numbers
Display the Position of the Faulty Dets
Display the Relevent Error Messages
E

FIG 9


D
Transmit the "SYNCHRONISE" Command
Auxiliary Control Units
Transmit Delay Times to each Auxiliary Control Unit in turn
Auxiliary Control Units
Transmit the "PROGRAMME" Command
Auxiliary Control Units
Sound the Sirens
Transmit the "INITIATE" Command
Auxiliary Control Units
Transmit the "SHUTDOWN" Command
Auxiliary Control Units
END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FREE FACE

FIG 10